NASA-CR-203787

NAG-1-1095

7N-47-CR

021667

On The Utilization of Remotely Sensed Data in Support of the ARM Single Column Modeling Concept

Gerald G. Mace Thomas P. Ackerman

Department of Meteorology, The Pennsylvania State University

1. Introduction

Characterization of clouds and cloud-induced radiation feedback in climate models is recognized as a source of uncertainty in climate prediction. A great deal has been learned in this area recently with extended satellite analyses such as ERBE and ISCCP and also from intensive field operations (IFOs) like those conducted for Project FIRE. By necessity, IFOs are short in duration (typically four to six weeks) and generally result in only one or two case study periods. While this is sufficient for process studies of cloud microphysics and instantaneous radiative transfer, improvement of cloud and radiation parameterizations can most effectively be gained by applying the lessons learned from the IFOs to develop new parameterizations and improve existing ones. It is critical, however, that the parameterized quantities be rigorously verified against obs[illegible] opportunity for this type of veri[illegible] provided by the Department of Ener[illegible] Radiation Measurement (ARM) Prog[illegible]

No Report Date, [01/01/1992]

The ultimate goal of the AR[illegible] improvement of cloud and radiation [illegible] in GCMs. Toward this end, a netw[illegible] observational sites (known as the Clo[illegible] Testbed or CART) has been establ[illegible] inner array of NOAA's Wind Profiler Demonstration Network (WPDN). The CART site is composed of a heavily-instrumented Central Facility (CF) located 8 km south of Lamont, OK and several smaller extended and boundary sites. The WPDN profilers, the boundary radiosonde sites and the CF wind profilers, RASS and radiosodes characterize the large-scale meteorology on scales comparable to that resolvable by a GCM. By utilizing the observed fields as input to cloud and radiation parameterizations, the paramterized quantities can be compared to radiometric and cloud observations recorded at the CART site. This procedure can be extended by taking the diagnosed dynamic and physical state over the CART site to prognose the atmospheric condition. Verification of the single column model (SCM) can then be performed from observations. This type of diagnostic and prognostic single column modeling has distinct advantages over typical satellite-based verification techniques since the vertical distribution of clouds and the surface radiation are observed. This technique has the disadvantage of considering only a single geographical point, although long periods of analysis should alleviate this problem somewhat.

To initiate this conceptual approach, the thermal, wind and moisture fields must be described to first order from observations over the CART site. This includes the 3 wind components, T, and q, as well as their gradients and time derivatives in several vertical layers. Since long term diagnostics are required, the techniques used to derive the meteorological fields must be geared to routinely observed quantities. The horizontal wind components and their derivatives can normally be estimated from wind profiler data. However, in many circumstances, considerable uncertainty exists in the kinematic vertical velocity from the profiler network data. The vertical profile [illegible]cal and temporal characteristics of T can [illegible] from RASS. Currently, however, the [illegible]rivatives of T and an accurate description [illegible]or can only be derived from radiosondes [illegible]ic campaigns.

[illegible]is paper, we consider several techniques [illegible]e adiabatic vertical velocity and the [illegible]mperature gradient from remotely sensed [illegible]availble routinely. Consideration of the water vapor field will be deferred to a later paper. Since the CF RASS only recently became operational, we will concentrate on data collected during the FIRE II IFO held in Coffeyville, KS during November and December 1991. We will utilize WPDN data and radiosonde-derived thermal fields. It should be noted that these techniques should be most accurate when applied to combined profiler and RASS observations.

2. Methods and Results

Recently, Hermes (1991) described a technique that returns the temperature gradients given the profiler-derived horizontal wind field, the kinematic vertical velocity and a radiosonde time series located within a profiler polygon. With the first order spatial and temporal derivatives of the horizontal wind and w, the geostrophic winds can be estimated from the inviscid equations of motion (Zamora et. al, 1989). Then, by way of the thermal wind equation, information on the vertical profile of the geostrophic wind and a temperature profile implies knowledge of the horizontal temperature gradient. Hermes was able to display reasonable skill with this technique by comparing the retrieved gradients with those estimated from objectively analyzed radiosonde data.

In order to verify this method, we applied it to a period during the FIRE II IFO. The horizontal wind field and associated kinematic vertical velocity were derived from the WPDN and the radiosonde time series was obtained from numerous launches at Coffeyville. Verification data were obtained from a triangle of radiosonde sites surrounding Coffeyville. Fig. 1 shows typical results from this calculation. Significant disagreement is noted before 14 UTC while good agreement is obtained afterward. Note that 3 hourly soundings were conducted by all radiosonde sites after 12 UTC while 6 hourly soundings were conducted before.

Another verification of the derived quantities can be obtained by using the observed and retrieved values in the first law of thermodynamics to calculate the large scale heating rates. While the actual heating rates are not known, the heating rates calculated from the observed and derived quantities for this case study are much larger in magnitude than can be realistically expected: exceeding 10 k/day in clear air. Apart from the period between 18 and 23 UTC, when a mid and upper tropospheric cloud band passed through the region, it is difficult to attribute the calculated heating rates to other than observational error or to a failure of the retrieval technique or both.

It can be stated with reasonable certainty that the atmosphere is much closer to adiabatic than implied by the calculated heating rates. Therefore, if an adiabatic assumption is imposed on the atmospheric column, the resulting diagnostic quantities should be more realistic. However, in order to ensure an adiabatic solution, the kinematic vertical velocity must be replaced with its adiabatic counterpart. Furthermore, since the vertical velocity is now considered unknown, the geostrophic wind and therefore its vertical shear cannot be determined. All this results in seven unknowns. This includes the geostrophic wind components, their shear, the horizontal temperature gradient terms and the adiabatic vertical velocity. By making the assumption that the vertical shear of the ageostrophic wind is negligible, (Neiman and Shapiro, 1989), the number of unknowns can be reduced to five since the shear of the geostrophic wind becomes the shear of the observed wind. By writing the inviscid equations of motion, the first law of thermodynamics and the approximate thermal wind equations, a linear system of five equations with five unknowns can be constructed and solved with standard techniques. We applied this method to output from the Mesoscale Analysis and Prediction System (MAPS) (Benjamin et al., 1991) in a simulation experiment where the model's winds were interpolated to the WPDN profiler locations and the thermal fields to Coffeyville. An example of the adiabatic vertical velocities and temperature advection compared to the values derived from the model gridpoint data is shown in Fig. 2. Reasonable agreement can be seen in this comparison except for 27 November when a strong jet streak propagated over the region. This highlights a weakness of the assumption imposed on the thermal wind equation that the vertical shear of the geostrophic wind is just the shear of the observed wind.

As shown by Neiman and Shapiro (1989), the approximated thermal wind equation should not be used in curved flow or near strong shears. To treat these situations, the vertical shear of the geostrophic wind is written as a difference formula from above. Specifying the geostrophic wind at at 14 km to be the observed wind, the linear system of five equations with five unknowns is reconstructed and the solution proceeds downward. The geostrophic wind in the adjacent layer above is then used in the current inversion. This requires specification of the geostrophic wind at a single level at the top of the column. Results for Nov. 26 1991 are shown in Fig. 3.

3. Summary

We have briefly described several techniques that will return a diagnostic description of the atmospheric column over the ARM CART site that can be used in a SCM driven by hourly-observed data. These techniques rely exclusively on profiler and RASS observations collected by the WPDN and CART CF instruments. While we used simulated RASS data in this abstract, experiments with the CART CF 50 MHz RASS and WPDN profilers are in progress.

References:

Hermes, L. G., 1991: *Mon. Wea. Rev.*, **119**, 1693-1712.

Neiman, P. J. and M. A. Shapiro, 1989: *Weather and Forecasting*, **4**, 222-233

Benjamin, S. G. et al. 1991: 9th Conference on Numerical Weather Prediciton, Denver, 14-18 October, Amer Meteor. Soc.

Zamora R.F. et al., 1987: *Mon. Wea. Rev.*, **115**, 871-884.

Acknowledgments

This research was supported by NASA grant NAG-1-1095 and NAG-1-999 and DOE grant DE-FG02-90ER61071. This work was performed while one of us (GM) held a NASA Goddard Graduate Student Fellowship. We would like to thank Stan Benjamin for supplying the MAPS data and Eugene Clothiaux for many insightful comments relating to this work.

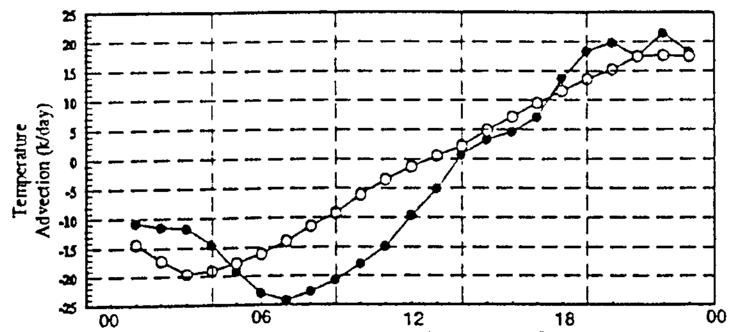

Fig. 1. Temperature advections at 9 km over Coffeyville, Kansas on 26 Nov. 1991. The filled circles represent calculated values while the open circles are from a surrounding radiosonde triangle. Time along the abscissa is UTC.

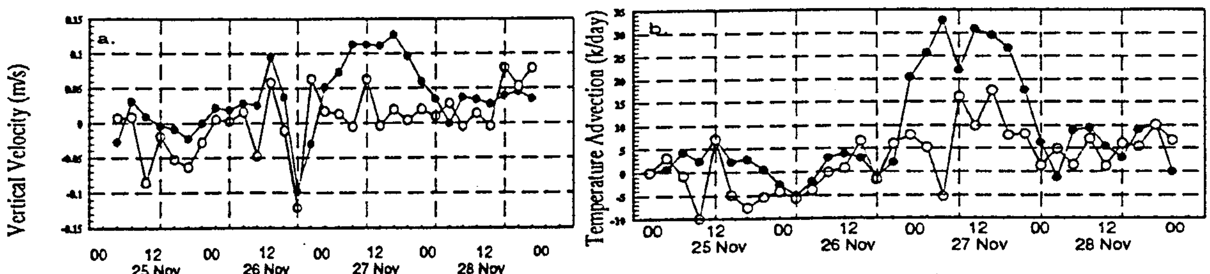

Fig. 2. Time series of a) adiabatic vertical velocity and b) temperature advection from 00 UTC 25 Nov. 1991 to 00 UTC 29 Nov. 1991. The solid circles represent values estimated using the adiabatic retrieval technique and the open circles are the values from the model gridpoint data.

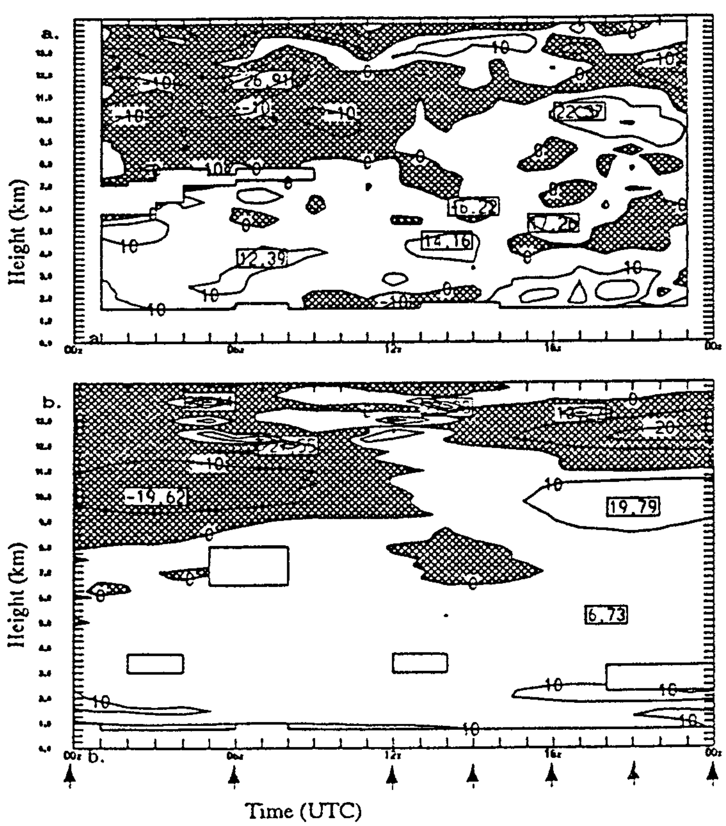

Fig. 3. Temperature advection from 00 UTC 26 Nov. 1991 to 00 UTC 27 Nov. 1991 as determined by a) modified adiabatic retrieval technique and b) objectively analyzed values from a triangle of radiosondes surrounding Coffeyville, KS. Contours are K/day and negative values are shaded. The ordinate is in km. Arrows denote the the times when radiosondes were launched.